

AN INVESTIGATION OF STRESS
CONCENTRATION FACTORS AROUND
SELECTED OPENINGS USING THE BRITTLE
LACQUER TECHNIQUE

DEAN K. MARQUARDT AND
ALLEN S. WATERS

Library
U. S. Naval Postgraduate School
Annapolis, Md.

224

AN INVESTIGATION OF STRESS CONCENTRATION
FACTORS AROUND SELECTED OPENINGS USING
THE BRITTLE LACQUER TECHNIQUE

Submitted to the Faculty of
Rensselaer Polytechnic Institute
In Partial Fulfillment of the
Requirements for the Degree of
Master of Civil Engineering.

by

Dean E. Marquardt

and

Allen S. Waters

TROY, NEW YORK
SEPTEMBER, 1948

Thane
M.B.

RECEIVED
JULY 10 1904
JULY 10 1904

Submitted to the Society of
Naturalists and Anthropologists
in partial fulfillment of the
requirements for the degree of
Master of Arts in Anthropology.

by

Thane M. B.

and

Alfred H. B.

NEW YORK
1904

TABLE OF CONTENTS

	Page
ABSTRACT.	1
INTRODUCTION.	2
PREPARATION OF MATERIALS.	6
INVESTIGATION USING MODERATE OVEN TEMPERATURES. . .	10
INVESTIGATION USING AIR DRYING.	15
THE USE OF HIGHER TEMPERATURES.	16
CONCLUSIONS	19
SUGGESTIONS FOR FUTURE INVESTIGATION.	22
DATA.	23
FIGURES AND ILLUSTRATIONS	36
BIBLIOGRAPHY.	50
INDEX.	51

TABLE OF CONTENTS

Page	
1	FOREWORD
2	INTRODUCTION
3	STATEMENT OF OBJECTS
4	INVESTIGATION INTO THE HISTORY OF THE
5	INVESTIGATION INTO THE HISTORY OF THE
6	INVESTIGATION INTO THE HISTORY OF THE
7	INVESTIGATION INTO THE HISTORY OF THE
8	INVESTIGATION INTO THE HISTORY OF THE
9	INVESTIGATION INTO THE HISTORY OF THE
10	INVESTIGATION INTO THE HISTORY OF THE
11	INVESTIGATION INTO THE HISTORY OF THE
12	INVESTIGATION INTO THE HISTORY OF THE
13	INVESTIGATION INTO THE HISTORY OF THE
14	INVESTIGATION INTO THE HISTORY OF THE
15	INVESTIGATION INTO THE HISTORY OF THE
16	INVESTIGATION INTO THE HISTORY OF THE
17	INVESTIGATION INTO THE HISTORY OF THE
18	INVESTIGATION INTO THE HISTORY OF THE
19	INVESTIGATION INTO THE HISTORY OF THE

ACKNOWLEDGMENT

The investigators wish to acknowledge their indebtedness to Professor E. H. Triethen, Mechanics Department, for his constant interest in the topic and his invaluable suggestions throughout the entire project. The authors are also indebted to Admiral L. B. Combs, Head of Civil Engineering Department, for his assistance in obtaining the services of the machine and welding shops at the Scotia Naval Depot; to the Public Works Department of Scotia; to Mr. David Howells II, Supervisor of Purchases, R.F.I., for his energetic service in obtaining many critical materials; to Mr. J. F. Throop, Materials Laboratory, for his suggestions in use of the laboratory equipment; and to Mr. George Sprong, machinist of Materials Laboratory, for his good-natured and skillful ability in helping prepare the test plates.

The investigators also wish to express their appreciation to all persons of the Bureau of Yards and Docks who cooperated so completely in furnishing the necessary details to initiate this project.

ABSTRACT

The objectives of this study were twofold. The first was an investigation of the use of the relatively new technique of brittle lacquer for determining quantitatively certain stress concentration factors. The succeeding objective, depending on satisfactory results of the first, was the actual determination of the factors for certain selected openings of particular shapes and sizes.

The authors have attempted to point out the practical problems and considerations involved in the use of brittle lacquer for a study of this kind. It was found that the technique is quite practicable, especially for odd shaped pieces or openings and that for large scale operations the investment in the brittle lacquer equipment and its use would be advisable.

The factors obtained for the particular openings used in this project are found in the data section of this report.

The objectives of this study were to determine the effectiveness of the use of the relatively new technique of optical recording for determining quantitatively certain stress concentration factors. The experimental method, depending on satisfactory results of the first, was the actual determination of the factors for which the optical recording of stresses was made.

The results have shown that the optical technique and considerations involved in the use of optical recording for a study of this kind. It was found that the technique is quite practical, especially for the study of stress concentration factors for which the optical recording of stresses is required and that for the same reason the use of optical recording in the study of stress concentration factors is a very effective method.

The factors obtained for the particular conditions used in this project are shown in the data section of this report.

INTRODUCTION

The object of this investigation was to determine if brittle lacquer could be successfully used to investigate stress concentration factors around circular, semi-elliptical, and bi-elliptical openings in flat plates subject to uni-axial loading; and, if so, to determine the stress concentration factors around these selected openings.

The term stress concentration factor as used in this paper is defined as the ratio of the maximum stress to the average stress in the minimum section. The term bi-elliptical opening is used in referring to openings consisting of halves of two ellipses having a common major intercept but different minor intercepts.

The importance of stress concentration factors around commonly used openings is obvious and has been the subject of considerable research and study. The particular openings chosen for this investigation were suggested by the Bureau of Yards and Docks of the U. S. Navy. They consisted of openings which are commonly used in drydock and tunnel construction and about which there is very limited data available. The tunnel pillar problem constituted one set of openings investigated. This consisted of semi-elliptical openings with bases along a common line separated by pillars of varying depth. The importance of this problem is obvious in tunnel

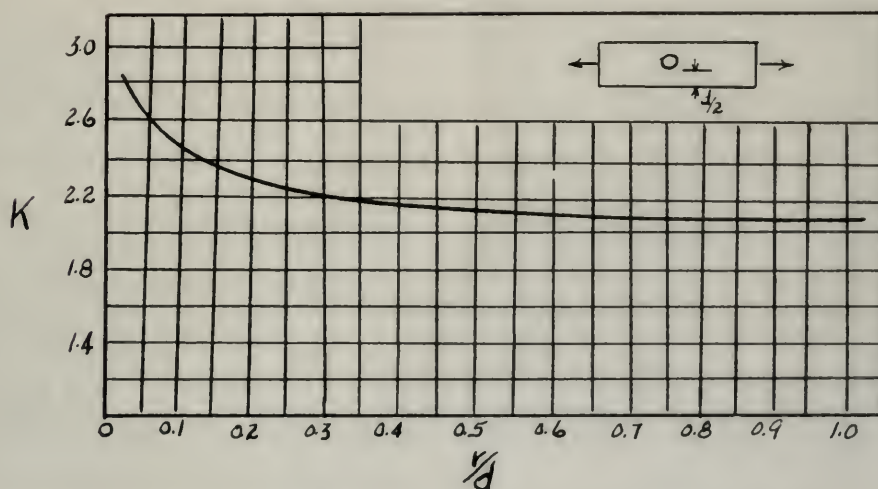
The object of this investigation was to determine if
certain factors could be statistically used to investigate
where non-resident factors are most likely to be found
and statistical analysis in this field would be most
useful. It was, to determine the factors which
would be most likely to be found.

The first concentration camp in Asia
opened in 1942 at the end of the war in the
Pacific. The camp was located in the
Philippines. The camp was used for
the detention of Japanese soldiers and
officers who had been captured by the
Americans. The camp was known as the
Camp O'Da. The camp was located in the
Philippines. The camp was used for
the detention of Japanese soldiers and
officers who had been captured by the
Americans. The camp was known as the
Camp O'Da.

[illegible]

work and other construction where openings of this type are frequently used.

The problem of stress concentrations around simple openings, such as a small circular opening in a plate of infinite width, is one which has been thoroughly analyzed and studied. The theoretical analysis of this problem gives a stress concentration factor of three where the width is great compared to the diameter of the hole. The variation of the factor with the ratio of radius of hole to width of plate is reproduced below from "Strength of Materials"--Part II by S. Timoshenko. It can be seen that the factor



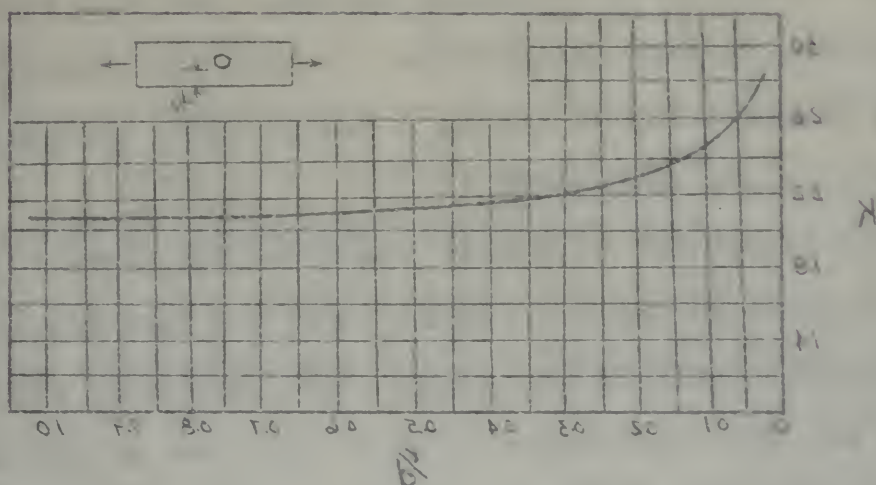
decreases considerably as the ratio r/d increases.

For elliptical holes the following is quoted from the above reference: "In the case of a small elliptical hole in a plate the maximum stress is at the ends of the horizontal axis of the hole, and is given by the equation:

$$f_{\max.} = f(1 + 2a/b)$$

with and other communication means consisting of this type are
 frequently used.

The problem of these communications around electric
 circuits, which as a small circuit working in a state of
 infinite time, is one which has been thoroughly analyzed
 and studied. The theoretical analysis of this problem
 gives a series of communication factors of which some are shown
 in Figure 1. The value of the factor of the factor is
 given of the factor with the value of factor of factor of factor
 of factor is represented below the "factor of factor" --
 and it is given by the factor. It is given by the factor



decrease considerably as the ratio 1/10 increases.
 The typical factor and following is noted from the
 factor of factor. In the case of a small circuit factor
 in a state the maximum factor is at the end of the factor
 and it is given by the factor.

$$E_{max} = 1/1 + 1/10$$

where f is the tensile stress applied at the ends of the plate. This stress increases with the ratio a/b , so that a very narrow hole perpendicular to the direction of tension produces a very high stress concentration." The above reference gives no indication that the stress concentration factor might vary with the ratio of the width of opening to the width of the plate. This is a summary of the meager information available on the problem.

The problem was not only the one of determining the stress concentration factors for the three types of openings suggested, but also of determining the variation of the factor for multiple openings of each type with varying depths of pillars between. A theoretical analysis would not only be extremely complex, but would be of doubtful practical value. From the practical stand-point there were two methods available for investigation of the problem: photoelasticity and brittle lacquer. Strain gages would only give an average value of strain over the gage length. This could cause an appreciable and indeterminate error even over a $1/8$ inch gage length. Several factors favored the use of brittle lacquer. Many tests could be run in the limited time available. The technique is fairly new and does not require extensive preparation. It was felt that the results could be checked by the photoelastic method if time permitted.

The Navy Department wished to obtain the stress concentration factors for plates subject to a uniform compressive

[illegible]

The system was not only the most of maintaining the
these communication is also for the three types of signals
collected, but also of maintaining the relation to the
factor the subject speaks of each type with varying degree
of clarity between. A theoretical weight is given to each
on extremely complex, but would be of somewhat practical
value. From the practical stand-point there was no reason
available for investigation of the problem, particularly
was not the system. While there would give a rough
value of error over the page length. This could be used as
theoretical and experimental error over a 1/8 inch page
length. Several factors entered the use of metric system.
They could be used in the United States system. The
technology is highly new and some new methods are
possible. It was well known the metric system was needed by
the scientific world in the present.

The Navy Department advised in 1941 that the United States Navy was not planning to build a fleet of aircraft carriers.

load. There were many difficulties, however, which would be encountered in the use of brittle lacquer in testing compression loads. The plates would have to be coated under load, then allowed to dry and the load released. Such a procedure would be extremely cumbersome with the equipment available. Since the load would be uni-axial in any case, the investigation was conducted with tension loads. The factors will, of course, be identical for both tension and compression loads.

During the course of the experiment the investigation was carried out in three principal parts. The first part consisted of tests using moderate oven temperatures for drying; the second part, drying in air; the third part, using higher temperatures in conjunction with another research project.

PREPARATION OF MATERIALS

After having determined the number and type of openings to be tested, the investigators were faced with the problem of determining the material and dimensions of the specimens and the design and construction of the necessary apparatus for testing the specimens. The material to be used for the specimens should have two properties: it should have a low modulus of elasticity, to yield a maximum strain with the least stress, thus reducing the load required to fracture the lacquer; and it must have a sufficiently high yield point to sustain strains of at least five times that required to fracture the lacquer without yielding. This is necessary in order to examine the strains over the entire plate without causing local yielding around the openings. The material which best fulfilled these qualifications was 24 ST aluminum, which has a modulus of 10,300,000 psi and a tensile strength of 44,000 psi.

The thickness of the plate should be the smallest which would allow handling and working without warping. The investigators decided to use 1/8" plate for the tests. However, since this was not available, 3/16" plate was substituted.

The relative dimensions of the plates and openings as prescribed by the Bureau of Yards and Docks are as follows:

Circular openings-- $r/h = 1/15$ or $1/20$ where r is radius of opening and h is depth of plate.

Half-elliptical openings-- $a/h = c/2h = 1/15$ or $1/20$ where a is minor intercept and c is major intercept.

Bi-elliptical openings--same as semi-elliptical openings but with bottom minor intercept of $a/3$.

The selection of the proper scale was very important for the proper interpretation of results. In determining the actual dimensions of the openings, the investigators felt that the minimum depth of opening should be $3/4"$ to facilitate fabrication of the samples and examination of the lacquer during testing. This depth of opening would require a clear depth of plate between $11.25"$ and $15"$. The maximum width of any opening would then be $3"$. In order to test two or more openings with varying depths between, the width of the plate must be about $16"$ to $18"$. Actually $3/4"$ was used for the a and r dimensions indicated above. The clear depth of plate was about $13"$ and the width about $16"$ or $18"$.

The fabrication of the circular holes presented no difficulties. The holes were drilled and reamed to size. The edges of the holes were polished to remove the rim left by the reaming operation, then checked to make sure the edges of the holes were perpendicular to the faces of the plates. Care was taken to insure that all holes had sharp, square

The relative dimensions of the plates and openings as
 specified by the Bureau of Roads and Bridges are as follows:
 distance openings- $2\frac{1}{2}$ "- $3\frac{1}{2}$ " or $1\frac{1}{2}$ " or $1\frac{1}{4}$ " or $1\frac{1}{2}$ " or $1\frac{1}{4}$ "
 of opening and g is depth of plate.

Self-aligning openings- $2\frac{1}{2}$ "- $3\frac{1}{2}$ " or $1\frac{1}{2}$ " or $1\frac{1}{4}$ " or $1\frac{1}{2}$ "
 g is also thickness and g is also interval.

Self-aligning openings- $2\frac{1}{2}$ "- $3\frac{1}{2}$ " or $1\frac{1}{2}$ " or $1\frac{1}{4}$ " or $1\frac{1}{2}$ "
 Set with system about thickness of $2\frac{1}{2}$ ".

The selection of the proper plate and opening for
 the proper investigation of results. In determining the

actual dimensions of the openings, the following table gives
 the minimum depth of opening should be $2\frac{1}{2}$ " or $1\frac{1}{2}$ " or $1\frac{1}{4}$ " or $1\frac{1}{2}$ "

Location of the openings and thickness of the plates
 during testing. This depth of opening should require a clear

depth of plate between $11\frac{1}{2}$ " and $12\frac{1}{2}$ ". The minimum depth of
 the opening should be $2\frac{1}{2}$ ". In order to have the same

openings with varying depths between the ends of the plate
 must be kept $12\frac{1}{2}$ " to $13\frac{1}{2}$ ". Actually $2\frac{1}{2}$ " was used for the g

and a systematic thickness of the plate depth of plate
 was about $12\frac{1}{2}$ " and the plate about $2\frac{1}{2}$ " to $12\frac{1}{2}$ ".

The location of the openings was determined by
 differential. The holes were drilled and reamed to size.

The edges of the plates were polished to remove the burr
 of the opening operation, then covered to save the edges

edges were also polished to the ends of the plates.
 Care was taken to insure that all holes and edges, etc.

edges without any overhang or rounding.

The semi-elliptical and bi-elliptical holes presented a considerable fabrication problem. There was neither time nor facilities available to obtain dies to punch the openings. The only solution seemed to be to drill and file the openings to proper size. The pattern was made by scribing a perfect ellipse on a plate using two pins and a taut cord. This plate was then used as a pattern for the other openings to insure uniformity. While this was a very tedious procedure, the openings were very carefully made to the precision desired. The edges were carefully filed to right angles and the corners were filed to the exact contour desired. All corners and edges were then polished smooth with emery cloth. It was felt that this was largely responsible for the uniformity of the results obtained.

The openings tested are illustrated on Figure I. Besides the tests of single openings of the relative dimensions illustrated, tests were made using plates with the following combinations of openings:

1. three circular openings 3" o.c.
2. two semi-elliptical openings 5", 6" and 7" o.c.
3. two bi-elliptical openings 5", 6" and 7" o.c.

It was hoped that the experiments would illustrate any variation in stress concentration factor with variation in pillar depth.

about without any covering or wrapping.

The wood-kiln, being an old-fashioned one, was

a considerable time before the wood was dried.

The wood-kiln was used to dry the wood.

The only reason for using the wood-kiln

was to dry the wood. The wood was

used for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

good for a long time and was very

The load to be sustained by the testing jig was computed as follows:

Average minimum strain to fracture lacquer--0.001 in./in.
Average stress in gross cross-section of plate--
 $0.001 \times 10,300,000 = 10,300$ psi.
Gross area of plate-- $3/16 \times 18 = 3.37$ sq. in.
Total load-- $3.37 \times 10,300 = 34,700$ lbs.

The jig was then designed to apply this load uniformly over an 18" length without appreciable deflection. The plans for this jig are included in this paper. The load was transmitted from the jig to the plates through $\frac{1}{2}$ " chrome steel pins fitted in machined holes $1\frac{1}{2}$ o.c. This jig proved highly satisfactory throughout the experiments.

Average minimum value in the above range is 10.000
 Average maximum value in the above range is 10.000
 Average minimum value in the above range is 10.000
 Average maximum value in the above range is 10.000

INVESTIGATION USING MODERATE
OVEN TEMPERATURES FOR DRYING

On the advice of Prof. R. E. Trathen, the first three tests were made using the oven-drying technique which was concurrently being investigated by J. H. Wilson and B. T. Dibble. This technique was expected to give much greater sensitivity than that obtained by the usual method of air-drying the lacquer.

In this phase of the investigation the conventional method of determining and applying the proper lacquer was used. The plates and calibration bars were first coated with aluminum undercoating for all runs.

The optimum lacquer for the spraying conditions was then applied to the plates. For the first run the entire depth of the plates was sprayed to test the jig for uniform load across the edge of the plate. For the other runs the plates were sprayed only around the openings. The plates and calibration bars were then placed in the oven at the temperatures indicated. The usual steel calibration bars were used for calibrating.

After drying, the plates and calibration bars were removed from the oven and placed in the laboratory near the testing machine. At least twenty minutes elapsed before testing any plate to insure cooling to room temperature. The temperature in the laboratory during testing was recorded.

On the matter of 1901, A. B. Freeman, the first known
person who was using the word "freedom" in the sense
concerned with being investigated by J. E. Simon and J. E.
Hibbs. This investigation was reported in the same paper
separately, than that contained by the same person of the
same time.

In this phase of the investigation the experimental method of determining and applying the proper degree was used. The glass was calibrated with water first cooled with alcohol and then with alcohol.

[illegible]

After dinner, the players and spectators were
entertained from the open air placed in the laboratory near the
lecturing machine. At least twenty minutes elapsed before
leaving and going to lecture rooms in some excitement.
The excitement in the laboratory, during leaving and returning.

The tests were made in a Southwark-Emery 100,000 lb. testing machine. The procedure used during testing was as follows:

A plate was inserted in the testing jig and all pins were inserted in the holes. The plate was carefully examined for crazing or cracks caused by driving the pins. An observer was stationed on each side of the plate and load was applied. A stop watch was used to clock the time from the beginning of application of load until the first cracks appeared. The time and load of the first cracks were recorded. The plate was then examined without further increase in load, and any irregularities were noted.

After examination, more load was applied in varying increments on the first run to obtain stress patterns over the whole plate. By carefully watching the lacquer at some distance from the openings it was determined that cracks appeared over the entire width of the plate at the same load. This indicated that the load was being applied uniformly at the edges, at least within the accuracy of the brittle lacquer. Photographs of the stress patterns obtained from the first run are included in a later section.

At the openings cracks would usually appear at all corners simultaneously, or nearly so. Sometimes there would be only one crack at a corner, but usually there would be two or three cracks at the first fracture. These cracks were about $1/8$ " long. Their locations with respect to the

The tracks were made in a southerly-southwest 100,000 ft.
 falling machine. The specimens found during testing are as
 follows:

A piece was located in the testing rig and was
 who inspected in the hole. The piece was carefully examined
 the raising of water caused by water in the hole. The
 water was observed on each side of the piece and then was
 raised. A piece of water was used to place the piece in the
 beginning of operation of the test until the piece was
 displaced. The first and last of the first piece were
 output. The piece was then examined without further increase
 in test, and any irregularities were noted.

After examination, more load was applied to testing
 specimens on the test and to obtain better results over
 the whole piece. By carefully watching the behavior of some
 specimens from the beginning to the end of the test
 appeared over the entire width of the piece at the same time.
 This indicated that the load was being applied uniformly at
 the same, at least within the capacity of the machine
 tested. Photographs of the specimens before and after the
 test were also included in a later section.

In the testing cracks would usually appear at the
 corners, especially at the top. Sometimes they would
 be only one corner at a corner, but usually there would be
 two or three corners at the same time. These cracks
 were about 1/2" long. Their location was noted by the

corners for the various types of openings are indicated in the sketches below.



The stress concentration factors were determined from the data as follows:

The calibration strain was corrected for creep during the time of loading using the creep correction curve reproduced herein as Figure 3. This corrected strain was then multiplied by the modulus of elasticity--10,300,000 psi.--to obtain the stress at the point where the cracks occurred. The average stress over the net area of the plate was found by dividing the load on the plate at the time of the first cracks by the net area of the plate. The ratio of the stress at the cracks to the average stress is the stress concentration factor. The factors for the first three runs were then tabulated and examined.

At this point in the investigation it became apparent that the results were very low and erratic. After much deliberation it was finally decided that the procedure of using steel calibration bars and aluminum samples was decidedly faulty. Upon investigation it was determined that the linear coefficient of thermal expansion for steel was

compare the two values of σ and σ_0 and find that the difference is small.



The three configurations shown are related by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

The configuration shown is related to the other two by the following relations:

approximately $0.0000065/^{\circ}\text{F.}$ as compared to about $0.000013/^{\circ}\text{F.}$ for the aluminum. The effect of this difference was as follows:

After spraying, the plates and calibration bars were placed in the oven while the lacquer was in a plastic condition. During the drying period the temperature was maintained constant. Upon removing the plates and bars from the oven, however, the aluminum plates would contract much more than the steel bars. This would have the effect of placing an initial compression in the lacquer on the aluminum plates corresponding to the difference in contraction between the aluminum and the steel. This compression effect would be maintained until the plate was loaded in tension. During this time, however, the effect would be somewhat reduced by creep in the lacquer. Upon loading the plate, a greater strain would then be required to fracture the lacquer. During the time the load was being applied creep would again take place in the lacquer, this time in the opposite direction. The net effect of creep would thus be rather uncertain.

The correction to compensate for this error was made quite simply. The difference in the linear coefficients of thermal expansion of the two materials was taken as $0.0000065/^{\circ}\text{F.}$ The difference in contractions between the two materials was this value multiplied by the temperature difference between the oven and the laboratory. This was the difference in strain induced in the lacquer by the

approximately 0.0000001, as compared to about 0.0000002.

For this reason, the effect of this difference was

follows:

After applying the same and calculation data were
 placed in the same table for the purpose of a direct com-
 parison. During the day, the temperature was fairly
 below normal. Upon removing the glass and after the
 over, however, the aluminum plates would conduct heat more
 than the steel plate. This would have the effect of heating
 in initial comparison in the liquid on the aluminum plates

corresponding to the difference in position between the

aluminum and the steel. This comparison effect would be

maintained until the glass was heated in water. During

the first, however, the effect would be somewhat reduced by

being in the liquid. Upon leaving the glass, a greater

effect would then be required to restore the liquid. During

the time the food was being applied to the glass again, the

glass in the liquid, this time in the opposite direction.

The net effect of these would not be rather uncertain.

The correction to comparison for this error was made

quite simple. The difference in the liquid coefficients of

thermal expansion of the two materials was taken as

0.0000002. The difference in coefficient of expansion was

two materials and this value multiplied by the difference

difference between the over and the liquid. This was

the difference in value caused by the liquid of the

unequal contractions of the materials. Creep was considered negligible as far as this strain was concerned. It was reasoned that whereas the time during which creep would take place to relieve the compression in the lacquer was considerably greater than that during which it would act to relieve the tension strain, since the tension strain would be much higher the net result would be unappreciable. The correction to be made was thus only the stress corresponding to the difference in contractions. This correction was applied to the creep-corrected calibration stress to obtain the actual stress at which the lacquer fractured. This procedure produced results which compared very favorably with those obtained using air-drying in the second phase of the investigation. Whereas there were certain errors in this procedure which were indeterminate, it was felt that they were of such small magnitude as not to affect the final result materially.

external conditions of the material. Given the conditions
 possible as far as this strain was concerned. It was
 reasoned that whereas the time during which each would
 take place is finite, the comparison in the subject was
 experimentally greater than that which was in fact and so
 relative the relative strain since the relative strain would
 be much larger for the same would be anticipated. The
 correction to be made was that only the strain corresponding
 to the difference in conditions. This correction was
 applied to the same-corrected subject strain as was
 the actual strain to which the subject was subjected. This
 experiment yielded results that showed that the strain of
 the subject relative to the strain in the second strain of
 the investigation. Hence there was certain errors in
 this procedure which were indicated, it was felt that
 they were of such small magnitude as not to affect the final
 result materially.

INVESTIGATION USING AIR DRYING

After consideration of the somewhat uncertain results of the first part of the investigation, the investigators decided to make several runs drying the plates in the conventional manner. The plates were coated with lacquer in the usual way, then dried at room temperature over night. The testing procedure was the same as for the previous runs.

Four runs were made in this manner, numbered 4 through 7. It was found that the calibration strains were considerably higher, but that the value of the factors did not vary beyond experimental limits. The dispersion was approximately the same as for the first three runs.

The reduced sensitivity of the lacquer when dried in air was not an inconvenience in this investigation. In fact, it may be that the results are slightly more accurate. Since the loads were higher, a small error in reading or calibration would have less effect on the factor.

This part of the investigation served mainly as a check on the first part and to obtain additional values to compute the mean factors. The results compared favorably with those obtained in the first three runs.

[illegible]

THE USE OF HIGHER TEMPERATURES IN CON-
JUNCTION WITH ANOTHER RESEARCH PROJECT

The next three runs, numbers 8, 9, and 10, were carried on in conjunction with a contemporary research project on the heat treatment of brittle lacquer by Lieutenants (junior grade) B. T. Dibble and J. N. Wilson, Civil Engineer Corps, U. S. Navy at R.P.I. These officers investigated the use of heat treatment to sensitize the lacquer and had at this time obtained sets of optimum conditions of lacquer numbers with corresponding degrees of heat treatment. It was desired to test these conditions of heat treatment on the complicated shapes and the practical problem of this stress concentration project. As indicated in runs 1, 2, and 3 of this project the Dibble-Wilson heat treatment of the test plates was used but at that early date a final set of optimum conditions had not been obtained and the investigation of this project showed a return to the standard method of air drying would be advisable.

Three sets of optimum conditions as suggested by Dibble and Wilson were set up for the same group of plates. The plates were sprayed, heat treated and tested with a run for each of the three sets of conditions. These runs are the following runs designated as numbers 8, 9, and 10.

The next item was the report of the committee on the subject of the investigation of the activities of the Communist Party in the United States. The committee reported that it had held several public hearings and had received many suggestions from the public. It had also conducted extensive research into the activities of the Communist Party and its various fronts. The committee found that the Communist Party was engaged in a systematic campaign to subvert the government and to establish a communist regime in the United States. It recommended that the government take prompt and effective action to counter the activities of the Communist Party and to protect the national security.

Three sets of engine conditions are suggested by

Run #8 consisted of plates, 1, 2, 3, and 4, the semi-ellipse group, sprayed with lacquer number 1205, heat treated for 28 hours in the oven at 124°F. , and slowly cooled to room temperature. Run #9 consisted of the same set of plates but with lacquer #1201 and oven temperature of 168°F. Run #10 was with same plates using lacquer #1203 and oven temperature 148°F.

These three separate runs served to confirm the Dibble-Wilson conclusions of increased sensitivity, with heat treatment which will undoubtedly be a tremendous stride in the success of brittle lacquers. However, this increased sensitivity for this one particular project on stress concentrations did not materially aid in the determinations of the factors. In run #8 the lacquer was so sensitive that the impact of driving the pins to set the plate in the jig produced small cracks at the critical points of the openings which again was proof of the increased sensitivity but which was undesirable for this project in that the resulting stress concentration factor for each plate in each run hinged on the accurate observation of the first minute crack in the lacquer under load.

The second apparent disadvantage of using heat treatment for this project was the necessity of using a calculated correction for the difference in coefficients of expansion between the aluminum test plates and the steel calibration strips. This calculated temperature correction stress at the

and he consisted of plates 1, 2, 3, and 4, the same-
 slight group, arranged with legend number 1000, and
 listed for 10 years in the case of 1940, and listed
 under the term "vegetation". The 10 consisted of the same
 set of plates but with legend 1001 and other legends
 of 1940, and 10 was the same plates being used 1900
 and other legends 1900.

These plates were used to produce the photo-
 graph collection of historical material, with other-
 best which will undoubtedly be a tremendous value in the
 history of certain legends. However, the legends are
 listed, the case was historical legend or other legend
 historical and not material, and in the collection of 1940
 legend. In the 10 legend was in material and the
 legend of during the time in the place in the 10 and
 dated with other as the legend of the legend
 with other the legend of the legend legend, and
 which was included for this legend in the legend
 which was included for this legend in the legend
 legend of the legend legend of the legend legend
 in the legend legend.

The second legend of legend of legend and legend-
 and for this legend was the legend of legend, and legend
 consisted for the legend of legend of legend
 between the legend legend and the legend legend
 legend. This legend legend legend legend of the

high oven temperature runs far outweighed the stress for the calibrated strain which was undesirable. For example, in run #9 the temperature correction amounted to 8170 psi while the stress obtained from the creep corrected calibration bar strain was only 3040 psi. An attempt was made to eliminate the necessity of this correction by the preparation of aluminum calibration strips, however the aluminum strips were of insufficient strength to withstand the deflection of the calibrator cam and all bars were permanently deformed. Had there been time available a new cam for the calibrator could have been prepared to give a much smaller deflection, therefore allowing the use of aluminum. Another possible remedy would have been to use calibration strips of 75 ST aluminum which has a yield strength of approximately 80,000 psi and could have withstood the deflection. Again the unavailability of materials and lack of time prevented this refinement.

A third disadvantage of these high heat treatments was the wide dispersion of results obtained as noted in the data for the three runs.

[illegible]

The wide distribution of certain conditions is noted in the following table.

CONCLUSIONS

The average values for the stress concentration factors and the maximum dispersions for the ten plates tested are tabulated below.

	Factor	Dispersion
Plate 1--single semi-ellipse	3.23	24.7%
2--two semi-ellipses 5" o.c.	2.60	18.5%
3--two semi-ellipses 6" o.c.	2.66	12.0%
4--two semi-ellipses 7" o.c.	3.04	18.5%
5--single bi-ellipse	3.28	20.5%
6--two bi-ellipses 5" o.c.	2.84	18.5%
7--two bi-ellipses 6" o.c.	2.63	25.0%
8--two bi-ellipses 7" o.c.	2.80	19.0%
9--single circular hole	1.94	11.3%
10--three circular holes 3" o.c.	1.82	20.3%

The conclusions which the authors have drawn from the above results and the experiment as a whole are as follows:

- (1) brittle lacquer is an excellent means for determining stress patterns in plates with openings.
- (2) brittle lacquer is an excellent means for locating points of stress concentration.
- (3) the dispersion may be as great as 25%, with occasional errors of much greater magnitude.
- (4) the stress concentration factors obtained by the use of the brittle lacquer technique are definitely lower than theoretical values or other available experimental values. For instance, the graph on page 3 gives a factor of about 2.6 for the opening in plate #9 as compared to an average value of 1.94 obtained by the brittle lacquer technique. It is believed that the factors for the elliptical openings are considerably lower than theoretical.

THE NATIONAL BUREAU OF INVESTIGATION
LEADS AND THE NATIONAL BUREAU OF INVESTIGATION
LEADS AND THE NATIONAL BUREAU OF INVESTIGATION

[illegible]

- (5) the tests showed that there was no noticeable variation in factors in the inside and outside corners of the openings in a plate.
- (6) there is no appreciable difference between the factors for semi-ellipses and bi-ellipses.
- (7) the factors seemed to vary according to this rule: a single opening causes the highest factor. For two openings the factor increases with the distance between the openings. For the openings tested all the factors for two openings were less than those for one. It seems likely that the factor for two openings would approach that for one opening as the distance between openings increases, but this was not definitely determined.
- (8) the shape of the stress pattern is affected by the curvature of the opening. Comparing figures 7, 13, and 14, one can see that as the curvature increases the isoentatic moves outward from the curved portion of the opening. This effect is most noticeable on Figure 7, the semi-ellipse. The isoentatics in this case are extended much farther above the curved portion than below the straight bottom of the opening. A study of this phenomenon was outside the scope of this investigation. Such a study might, however, throw considerable light on the effect of openings in plates.

The reason for the low values of stress concentration factors has not been determined. One possible solution is that the lacquer was thin over the edges of the openings and would therefore not fracture at as low a strain as the lacquer on the calibration bars. However, every possible means was taken to obtain a uniform thickness of lacquer at all points around the opening. The investigators are of the opinion that this did not have an appreciable effect on the factors obtained, but was mentioned merely to caution other investigators to use great care in applying the lacquer around openings.

Another possible cause of the low values obtained was the discontinuity of the lacquer near the edges of the openings. As far as can be determined from observing carefully the cracks on calibration bars it seemed that lacquer cracked at the edges of the bars at the same strain as in the body of the lacquer itself. However, this has not been thoroughly investigated and no definite statements can be made concerning it.

The great difficulty in this work is that the stress drops off so rapidly near the opening that a value obtained at only a minute distance from the opening would be considerably in error. As far as could be determined the stresses obtained in this investigation were the correct values, but perhaps there was some source of error at this critical point which has not as yet been recognized. It was felt that this is a particularly important phase of the use of brittle lacquer and would be a worthwhile problem for future investigation.

Any readers making a comparison of these factors with others are cautioned that these factors are based on the net area and not on gross area. Factors based on net area will be smaller than factors based on gross area.

SUGGESTIONS FOR FUTURE INVESTIGATION

The following suggestions for future investigation are set down by the authors:

- (1) The investigation of stress concentration factors for plates in compression might yield valuable information about the problem. Such an investigation would require special equipment and considerable time. The method of spraying while plate is under a compressive load, drying under load, and testing by relaxing load could be used.
- (2) An investigation using a jig which would clamp the plates would eliminate some of the troubles experienced from driving the pins in this investigation, therefore the increased sensitivity of heat treatment could be used.
- (3) The development of a technique which would guarantee a uniform thickness of lacquer inside and at the edges of the openings would probably yield more reliable results than the usual technique. A finer lower pressure spray or perhaps a brush could be used.
- (4) A study of the variation of stress concentration factors over a wider range of pillar depths would be of great value.
- (5) An investigation of the same openings using the photoelastic technique would be a valuable check on the results obtained.
- (6) In association with heat treatment the preparation of calibration strips of the same material as the test plates with possible pre-requisite preparation of a calibrator cam to give small deflections would eliminate the need of the large thermal expansion corrections that were necessary in this particular experiment. Or the preparation of calibration strips of 75 ST aluminum to withstand the deflection of the calibrator cam could likewise be done for use with aluminum plates.

DESCRIPTIONS OF TEST PLATES

<u>Plate No.</u>	<u>Average Thickness</u>	<u>Gross Width</u>	<u>Net Width</u>	<u>Gross Area</u>	<u>Net Area</u>
1	0.1870	15.88	12.75	2.97	2.39
2	0.1870	15.88	9.75	2.97	1.62
3	0.1880	15.88	9.81	2.90	1.64
4	0.1865	18.06	11.94	3.37	2.23
5	0.1865	15.88	12.81	2.96	2.38
6	0.1880	15.88	9.91	2.90	1.86
7	0.1885	18.06	12.00	3.41	2.27
8	0.1870	18.00	11.94	3.37	2.23
9	0.1870	15.88	14.38	2.97	2.69
10	0.1885	15.88	11.38	2.00	1.15

Plate No. 1 has one Semi-ellipse, centered

Plate No. 2 has two Semi-ellipses, 5"o.c.

Plate No. 3 has two Semi-ellipses, 6"o.c.

Plate No. 4 has two Semi-ellipses, 7"o.c.

Plate No. 5 has one Bi-ellipse, centered

Plate No. 6 has two Bi-ellipses, 5"o.c.

Plate No. 7 has two Bi-ellipses, 6"o.c.

Plate No. 8 has two Bi-ellipses, 7"o.c.

Plate No. 9 has one Circle, centered

Plate No. 10 has three Circles, 3"o.c.

Page No. 10 has some errors, corrected.
 Page No. 9 has some errors, corrected.
 Page No. 8 has some errors, corrected.
 Page No. 7 has some errors, corrected.
 Page No. 6 has some errors, corrected.
 Page No. 5 has some errors, corrected.
 Page No. 4 has some errors, corrected.
 Page No. 3 has some errors, corrected.
 Page No. 2 has some errors, corrected.
 Page No. 1 has some errors, corrected.

OBSERVED DATA

Run #1

July 28, 1948

All plates coated with #1207; dried 20 hours in oven at 90°F.
Room temperature during test 70°F.

Calibrations: 6.61, 6.57

average 6.09×10^{-4}

Plate	Load to heading	Time Sec.	Average Stress- Net Area	Corrected* Stress at Cracks	Factor
1	7550	1320	3160	10,940	3.47
2	4230	1140	4230	10,840	2.87
3	6500	80	3520	8780	2.62
4	7500	70	3370	8670	2.57
5	10,500	270	2510	8560	3.23
6	8000	90	4300	8880	2.07
7	10,000	150	4420	8980	2.03
8	8500	90	3800	8880	2.33
9	10,600	60	3950	8550	2.16
10	4000	30	1880	8370	4.48

* Corrected stress includes the following corrections:

- (1) for difference in coefficients of thermal expansion of steel calibration strip and aluminum test plates during cooling from 90°F. (oven temperature) to 70°F. (room temperature).

$$\text{Correction} = 65 \times 10^{-7} \times 10.3 \times 10^6 \times 20 = 1340 \text{ psi}$$

- (2) for creep during time of test, obtained from creep curves.

Sample: Plate No. 1.

Calibration strain is 6.09×10^{-4} inches/inch.

Strain corrected for creep during 1320 seconds is 9.30×10^{-4} inches/inch.

Corresponding stress $9.30 \times 10^{-4} \times 10.3 \times 10^6 = 9600 \text{ psi}$

Stress corrected for temperature = $9600 + 1340 = 10,940 \text{ psi}$.

1. The following is a list of the names of the persons who have been identified as having been in contact with the subject during the period from 1964 to 1968.

(S) For group sailing please see page 10.

4-10-1994

OBSERVED DATA

Run #2

July 29, 1948

All plates coated with #1207; dried 20 hours in oven at 110°F.
Room temperature 77°F.

Calibrations: 2.08, 3.08

average 2.58×10^{-4}

<u>Plate</u>	<u>Load to Reading</u>	<u>Time Sec.</u>	<u>Average Stress- Net Area</u>	<u>Corrected* Stress at Cracks</u>	<u>Factor</u>
1	6400	150	2680	5590	2.07
2	2500	5	1370	4910	3.58
3	2400	45	1310	5010	3.83
4	3500	60	1570	5350	3.41
5	4200	60	1750	5350	3.05
6	2500	75	1345	5400	4.01
7	5000	50	2190	5020	2.29
8	4000	150	1790	5590	3.11
9	No readings -- badly crazed.				
10	4500	30	2090	5220	2.50

* See Run #1

TABLE 1

1964, 1965, 1966

1967, 1968

All data were obtained from the same source, the U.S. Fish and Wildlife Service, and are presented in Table 1.

1964, 1965, 1966

1967, 1968

Year	Number of birds banded	Number of birds banded	Number of birds banded	Number of birds banded	Number of birds banded
1964	1000	1000	1000	1000	1000
1965	1000	1000	1000	1000	1000
1966	1000	1000	1000	1000	1000
1967	1000	1000	1000	1000	1000
1968	1000	1000	1000	1000	1000
1969	1000	1000	1000	1000	1000
1970	1000	1000	1000	1000	1000
1971	1000	1000	1000	1000	1000
1972	1000	1000	1000	1000	1000
1973	1000	1000	1000	1000	1000
1974	1000	1000	1000	1000	1000
1975	1000	1000	1000	1000	1000
1976	1000	1000	1000	1000	1000
1977	1000	1000	1000	1000	1000
1978	1000	1000	1000	1000	1000
1979	1000	1000	1000	1000	1000
1980	1000	1000	1000	1000	1000

1964, 1965, 1966

OBSERVED DATA

Run #3

July 29, 1948

All plates coated with #1208; dried 20 hours in oven at 100°F.
 Room temperature 80°F.

Calibrations: 3.1, 3.6

average 3.35×10^{-4}

<u>Plate</u>	<u>Load to Reading</u>	<u>Time Sec.</u>	<u>Average Stress- Net Area</u>	<u>Corrected* Stress at Cracks</u>	<u>Factor</u>
1	3900	15	1630	5140	3.15
2	4600	36	2520	5280	2.12
3	3400	20	1840	5180	2.88
4	2300	8	1030	5020	4.88
5	3200	9	1330	5020	3.77
6	3800	25	2040	5210	2.56
7	4000	17	1760	5140	2.93
8	4400	35	1960	5320	2.72
9	5300	10	1960	5070	2.06
10	5600	30	2600	5280	2.02

* See Run #1

GRAVITY DATA

July 29, 1948

Run 15

All points covered with 11805; dated 10 hours in week of 100.2.
 Hole complete 80.7.

average 2.50 x 10⁻⁴

Deflection: 2.1, 3.0

Time	Low to	Average	Corrected	Factor
Sec.	Reading	Net Area	Area at	
15	2400	1550	5140	2.15
20	2400	1550	5200	2.18
25	2400	1550	5180	2.20
30	2300	1550	5090	2.22
35	2300	1550	5090	2.24
40	2300	1550	5100	2.26
45	2300	1550	5140	2.28
50	2300	1550	5140	2.30
55	2300	1550	5140	2.32
60	2300	1550	5140	2.34
65	2300	1550	5140	2.36
70	2300	1550	5140	2.38
75	2300	1550	5140	2.40
80	2300	1550	5140	2.42
85	2300	1550	5140	2.44
90	2300	1550	5140	2.46
95	2300	1550	5140	2.48
100	2300	1550	5140	2.50

* see Run 11

OBSERVED DATA

Run #4

August 3, 1948

All plates coated with #1208; dried 26 hours at room temperature.

Calibrations: 5.8, 6.1

average 5.95×10^{-4}

<u>Plate</u>	<u>Load to Reading</u>	<u>Time Sec.</u>	<u>Average Stress-Net Area</u>	<u>Stress at Cracks</u>	<u>Factor</u>
1	5100	19	2130	6800	3.18
2	4600	22	2520	6870	2.72
3	5200	10	2820	6820	2.34
4	5800	23	2800	6870	2.63
5	5150	25	2160	6870	3.16
6	5040	25	2720	6870	2.52
7	6200	32	2720	6380	2.34
8	6000	28	2690	6300	2.34
9	10,800	42	4020	7110	1.77
10	9800	12	4560	6620	1.45

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED
DATE 01-10-2001 BY 60322 UCBAW

Year	1990	1991	1992	1993	1994
1990	1.00	1.00	1.00	1.00	1.00
1991	1.00	1.00	1.00	1.00	1.00
1992	1.00	1.00	1.00	1.00	1.00
1993	1.00	1.00	1.00	1.00	1.00
1994	1.00	1.00	1.00	1.00	1.00

OBSERVED DATA

Run #5

August 6, 1948

All plates coated with #1206; dried 17 hours at room temperature.

Calibration: 7.32×10^{-4}

<u>Plate</u>	<u>Load to Reading</u>	<u>Time Sec.</u>	<u>Average Stress- Net Area</u>	<u>Stress at Cracks</u>	<u>Factor</u>
1	8500	60	3570	8900	2.49
2	6100	14	3350	8210	2.45
3	5600	22	3040	8450	2.78
4	7100	60	3180	8900	2.80
5	8100	60	3400	8900	2.61
6	5800	25	3110	8450	2.71
7	6700	23	2940	8450	2.87
8	6100	20	2740	8390	3.05
9	14,000	66	5210	9000	1.72
10	11,200	22	5220	8450	1.61

11/11/1964

¹⁰ Of a 34.5% probability.

Grade	Lead to Loading	Time Sec.	Average Rate per hour	Distance of Crews	Factor
1	3400	40	50.00	1000	1.00
2	4100	44	37.50	8810	2.48
3	5000	50	30.00	6450	3.78
4	7100	60	17.50	5000	4.60
5	8100	66	24.00	3900	5.61
6	8300	70	17.10	4250	6.71
7	6700	70	24.40	3450	6.99
8	8100	80	27.60	3500	8.06
9	14,000	64	32.10	4000	11.76
10	11,000	52	34.60	3400	14.66

OBSERVED DATA

Run #6

August 7, 1948

All plates coated with #1206; dried 26 hours at room temperature.

Calibration: 8×10^{-4}

<u>Plate</u>	<u>Load to Heading</u>	<u>Time Sec.</u>	<u>Average Stress Net Area</u>	<u>Stress at Cracks</u>	<u>Factor</u>
1	6100	32	2550	9410	3.70
2	6000	26	3220	9270	2.87
3	6200	31	3370	9350	2.77
4	6300	30	2830	9300	3.30
5	6400	22	2670	9270	3.45
6	7100	31	3820	9350	2.44
7	8000	24	3820	9270	2.63
8	6100	18	2720	9090	3.33
9	13,100	50	4880	9670	1.98
10	9200	30	4270	9300	2.18

Year	Population	Area	Population	Area	Year
1970	1000	1000	1000	1000	1970
1971	1000	1000	1000	1000	1971
1972	1000	1000	1000	1000	1972
1973	1000	1000	1000	1000	1973
1974	1000	1000	1000	1000	1974
1975	1000	1000	1000	1000	1975
1976	1000	1000	1000	1000	1976
1977	1000	1000	1000	1000	1977
1978	1000	1000	1000	1000	1978
1979	1000	1000	1000	1000	1979
1980	1000	1000	1000	1000	1980

OBSERVED DATA

Run #7

August 10, 1948

All plates coated with #1205; dried 28 hours at room temperature.

Calibration: 8.26×10^{-4}

<u>Plate</u>	<u>Load to Reading</u>	<u>Time Sec.</u>	<u>Average Stress- Net Area</u>	<u>Stress at Cracks</u>	<u>Factor</u>
1	5800	25	2420	8150	3.37
2	5100	21	2800	8120	2.90
3	6100	30	3310	8300	2.49
4	5100	20	2280	8090	3.51
5	5400	19	2250	8090	3.58
6	5100	19	2740	8090	2.94
7	5600	21	2460	8120	3.29
8	6800	32	3040	8300	2.73
9	6600	29	2450	8300	3.38
10	9800	48	4560	8450	1.85

CONCRETE DATA

August 10, 1948

Run 7

All trials coated with 1100; dried 10 hours at room temperature.

Collapsions: 0.10 x 10⁻³

Load to collapse psi	Time sec.	Average strain- rate in/in	Strain at collapse	Factor
1	20	2400	810	1.70
2	21	2800	810	1.70
3	20	3210	820	1.66
4	20	3200	800	1.61
5	19	3200	800	1.56
6	19	3740	800	1.54
7	21	4480	810	1.59
8	20	5040	820	1.70
9	20	6400	800	1.58
10	20	7500	840	1.60

OBSERVED DATA

Run #8

August 12, 1948

Plates 1, 2, 3, and 4 coated with #1205; heat treated at 124°F. for 28 hours. Room temperature 78°F.

Calibration: 2.0×10^{-4}

<u>Plate</u>	<u>Load to Reading</u>	<u>Time Sec.</u>	<u>Average Stress- Net Area</u>	<u>Corrected* Stress at Cracks</u>	<u>Factor</u>
1	3000	9	1250	5290	4.23
2	3500	17	1920	5350	2.78
3	4200	27	2280	5410	2.37
4	2800	9	1270	5290	4.16

* See Run #1

STANDARD DATA

August 11, 1966

and 18

Wicks J. J. and J. J. Wicks with J. J. Wicks and J. J. Wicks
124° E. for 60 miles. From Washington 107°.

Calibration: 2.0×10^{-4}

Time	Rate	Count Rate	Count Rate	Count Rate	Count Rate
1	1000	1000	1000	1000	1000
2	1000	1000	1000	1000	1000
3	1000	1000	1000	1000	1000
4	1000	1000	1000	1000	1000
5	1000	1000	1000	1000	1000
6	1000	1000	1000	1000	1000
7	1000	1000	1000	1000	1000
8	1000	1000	1000	1000	1000
9	1000	1000	1000	1000	1000
10	1000	1000	1000	1000	1000
11	1000	1000	1000	1000	1000
12	1000	1000	1000	1000	1000
13	1000	1000	1000	1000	1000
14	1000	1000	1000	1000	1000
15	1000	1000	1000	1000	1000
16	1000	1000	1000	1000	1000
17	1000	1000	1000	1000	1000
18	1000	1000	1000	1000	1000

OBSERVED DATA

Run #9

August 17, 1948

Plates 1 to 4 coated with #1201; heat treated 20 hours in oven at 168°F. Cooled in oven to room temperature 76°F.

Calibration: 2.7×10^{-4} inches/inch

Plate	Load to Reading	Time Sec.	Average Stress- Net Area	Corrected* Stress at Cracks	Factor
1	2600	13	1090	9210	8.47
2	3000	16	1650	9240	5.60
3	2000	8	1080	9150	8.48
4	3000	21	1340	9280	6.92

* See Run #1

STATION 102A

August 14, 1949

Wm. V.

Station 102A is a small, high, steep, rocky hill, about 100 ft. high, located in the center of the station. It is covered with low-lying vegetation, mostly grass and small shrubs.

Station 102A is a small, high, steep, rocky hill, about 100 ft. high, located in the center of the station. It is covered with low-lying vegetation, mostly grass and small shrubs.

Time	Loc.	Time	Loc.	Time	Loc.
1	1000	12	1000	13	1000
2	1000	14	1000	15	1000
3	1000	16	1000	17	1000
4	1000	18	1000	19	1000

See also 102B

OBSERVED DATA

Run #10

August 18, 1948

Plates 1 to 4 coated with #1203; heat treated 20 hours in oven at 148°F. Cooled in oven to room temperature of 76°F.

Calibration: 4.6×10^{-4} inches/inch

Plate	Load to Reading	Time Sec.	Average Stress- Net Area	Corrected* Stress at Cracks	Factor
1	4900	31	2050	10,230	5.00
2	5300	20	2920	10,100	3.47
3	5000	22	2720	10,140	3.71
4	4400	32	1970	10,230	5.20

* See Run #1

RECEIVED

January 10, 1945

San Jo

Placed in to a sealed with glass; heat treated in water at 150°C. - tested in order to determine properties of YAG.

Calculation: 4.8×10^{-8} atoms/cm³

Plate	Load to fracture	Time (sec.)	Average stress - test stress	Calculated stress in YAG	YAG stress
1	4500	22	2000	10,100	10.0
2	4700	30	2040	10,100	10.4
3	5000	33	2100	10,100	11.1
4	4400	25	1970	10,100	10.8

San Jo

COMPUTATION AND COMPARISONS OF FINAL FACTORS

Plate	Runs							Total	Average
	I	II	III	IV	V	VI	VII		
1	3.47	2.07*	3.15	3.18	2.49	3.70	3.37	19.36	3.23
2	2.57	3.58*	2.12	2.72	2.45	2.87	2.90	15.63	2.60
3	2.69	3.83*	2.88	2.34	2.78	2.77	2.49	15.95	2.66
4	2.57	3.41	4.88*	2.63	2.80	3.30	3.51	18.22	3.04
5	3.33	3.05	3.77	3.16	2.61	3.45	3.58	22.95	3.28
6	2.07	4.01*	2.56	2.52	2.71	2.44	2.94	15.24	2.54
7	2.03	2.29	2.93	2.34	2.87	2.63	3.29	18.38	2.63
8	2.33	3.11	2.72	2.34	3.05	3.33	2.73	19.61	2.80
9	2.16	----	2.06	1.77	1.72	1.98	3.38*	9.69	1.94
10	<u>4.48*</u>	<u>2.50*</u>	<u>2.02</u>	<u>1.45</u>	<u>1.61</u>	<u>2.18</u>	<u>1.85</u>	<u>9.11</u>	<u>1.82</u>
Total									
(1-8)	21.06	11.86	20.13	21.23	21.76	24.39	24.61		
Ave.	2.63	2.96	2.88	2.65	2.72	3.05	3.08		

* This value arbitrarily discarded as it differed from the mean for the plate by more than twenty-five per cent.

COMPARISON OF MEAN VALUES

Class	I	II	III	IV	V	VI	VII	Total
1	2.47	2.07	2.18	2.18	2.49	2.10	2.07	2.18
2	2.07	2.08	2.12	2.12	2.12	2.12	2.07	2.08
3	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
4	2.07	2.11	2.08	2.08	2.08	2.08	2.08	2.08
5	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
6	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
7	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
8	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
9	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
10	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Total	21.08	21.08	21.08	21.08	21.08	21.08	21.08	21.08

W. H. H. value (approximately) calculated as it differed from the mean for the class of more than twenty-five per cent.

EXPLANATION OF PHOTOGRAPHS ON FOLLOWING PAGES

Some of the following photographs were made of the test plates after a test run. A red dye etchant was used to accentuate the small cracks for better photographing purposes.

The photographs are primarily to show the stress distribution over the area surrounding the openings. For the actual calculation of the concentration factors only the first minute crack was necessary but the crack was too small to be photographed. Some photographs show the isoentatics for various loads and some clearer photographs show the isostatics. An isoentatic is a line drawn to join the ends of the cracks (isostatics) in the lacquer, thus is the locus of points of equal strain. An isostatic is an actual crack in the lacquer or the lines of failure of the coating. The directions of the principal stresses are tangent and perpendicular to the isostatics.¹ See Figure 14 for procedure for obtaining isoentatics.

1. A. J. Durelli, "What Kind of Information Does Brittle Lacquer Give", Product Engineering, June, 1948.

THEORY OF PHOTOGRAPHY IN POLARIS

Some of the following photographs were made of the
same place after a few days. A red line around was used
to indicate the small circles for better photographing
purpose.

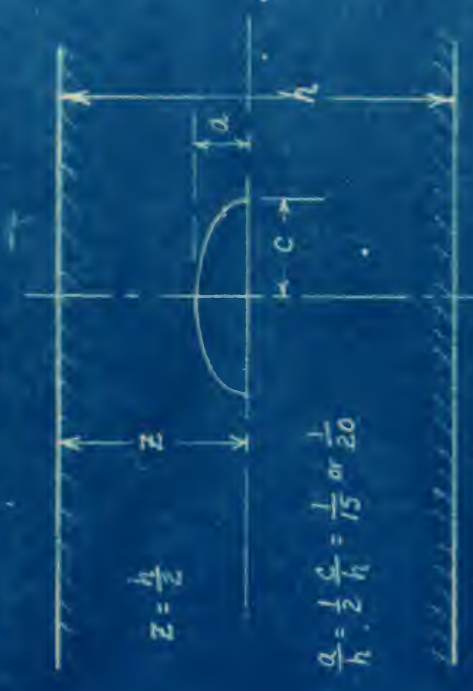
The photographs are arranged in order to show the
distribution over the area surrounding the opening. For
the actual calculation of the concentration of the
the first image was necessary but the error was too
small to be photographed. Some photographs show the
surface for various levels and some others photographs show
the horizontal. An isometric is a line drawn to join the
ends of the circles (horizontal) in the image, thus is the
image of points at equal level. An isometric is an actual
space in the image on the lines of level of the circle.
The divisions of the principal circles are shown and
perpendicular to the horizontal. The error is for purposes
for obtaining isometric.

RELATIVE DIMENSIONS OF PLATES AND OPENINGS

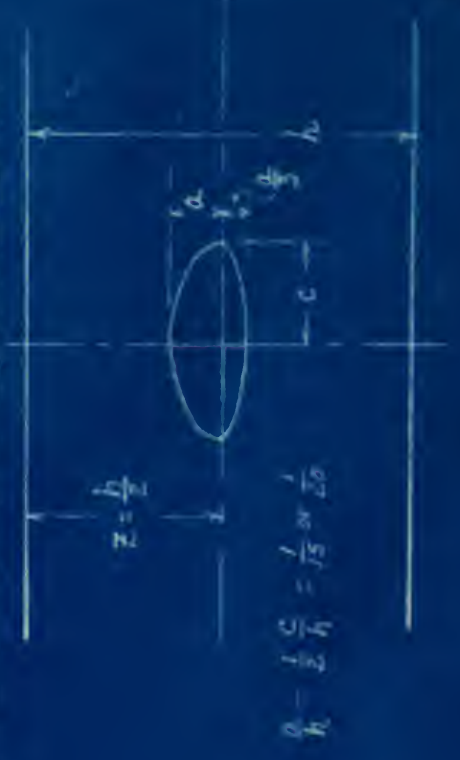
(A) CIRCULAR OPENINGS



(B) HALF-ELLIPTICAL OPENINGS, STRAIGHT BOTTOM



(C) HALF-ELLIPTICAL OPENINGS, CURVED BOTTOM



(D) PILLARS

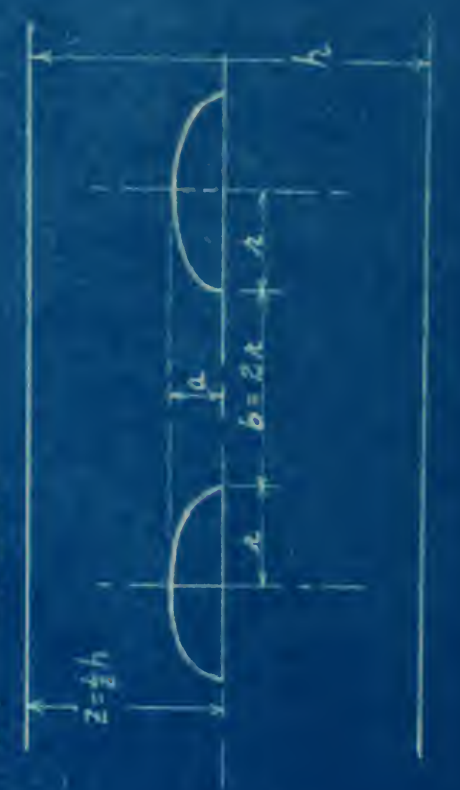


FIG. 1



STRESSCOAT CREEP CORRECTION CHART - I

Strain - in. per in. $\times 10^4$

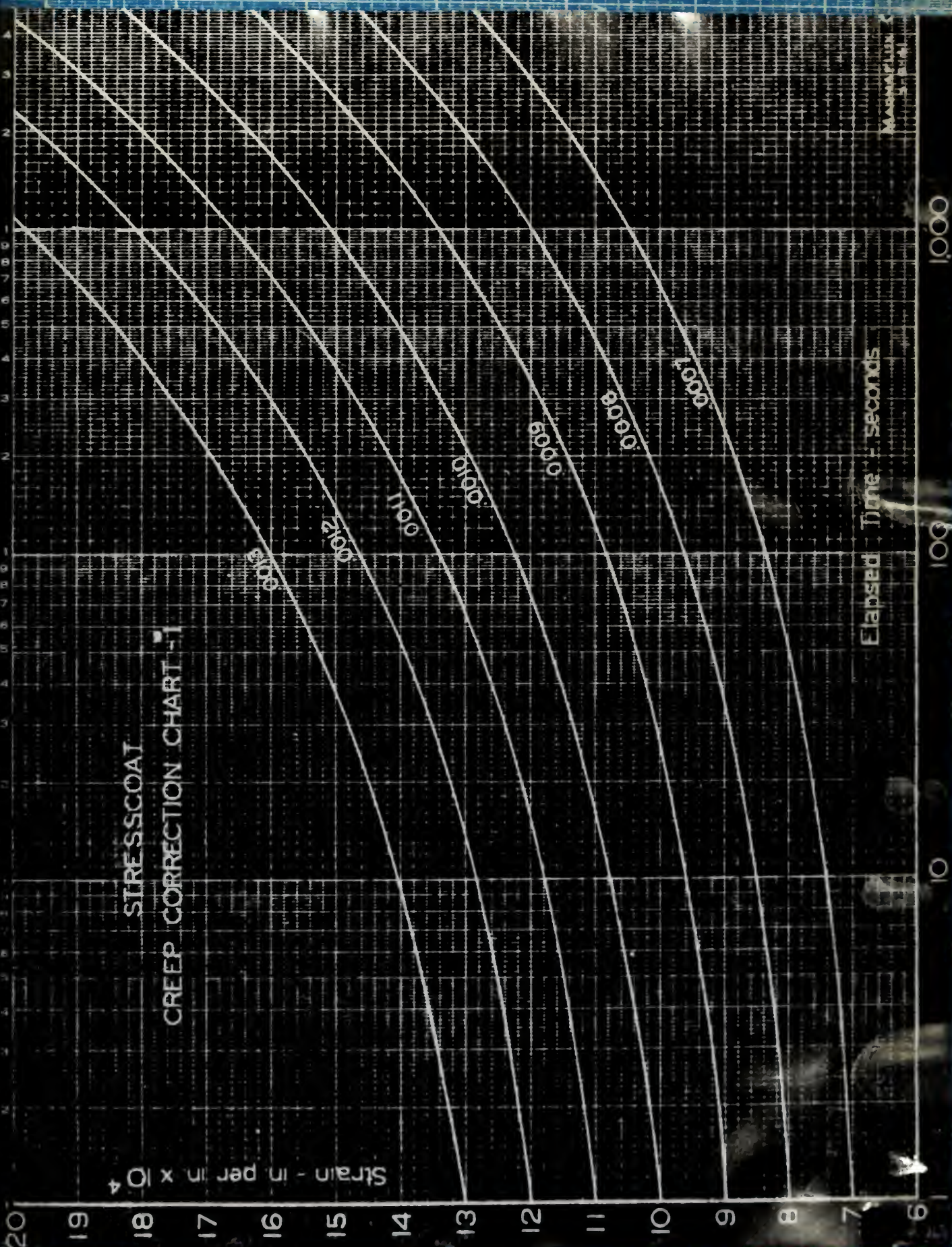
Elapsed Time - seconds

1000

100

10

MADE IN U.S.A.





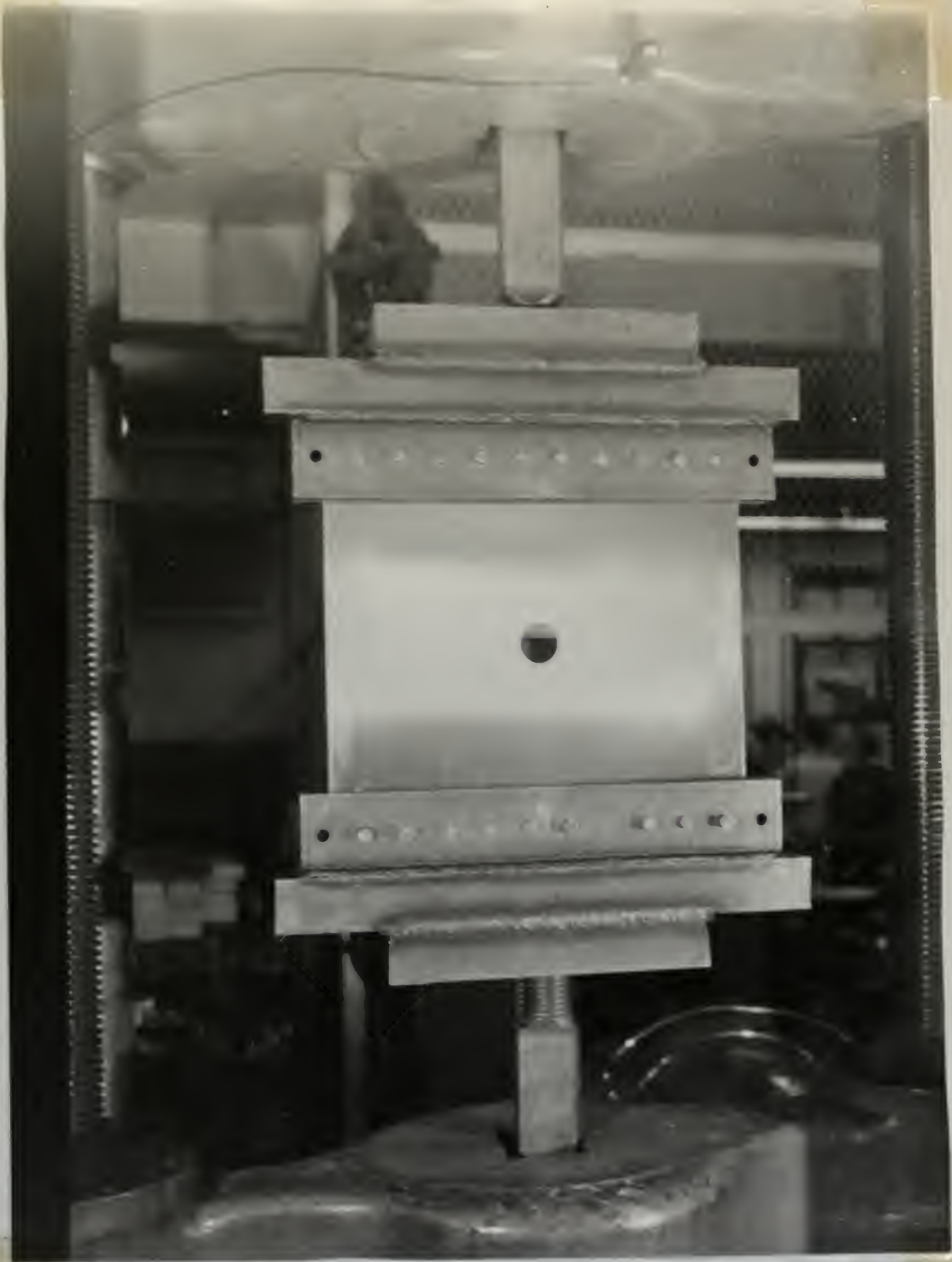


Fig. 4

This is a photograph of the apparatus set for a test run. It shows a front view of the jigs and the large bolt leading to the cross heads of the testing machine. Plate #9 is shown mounted in the jig. The wide light colored band across the center of the plate is the dried coating of lacquer.



Fig. 5

Side view of jig with plate mounted.

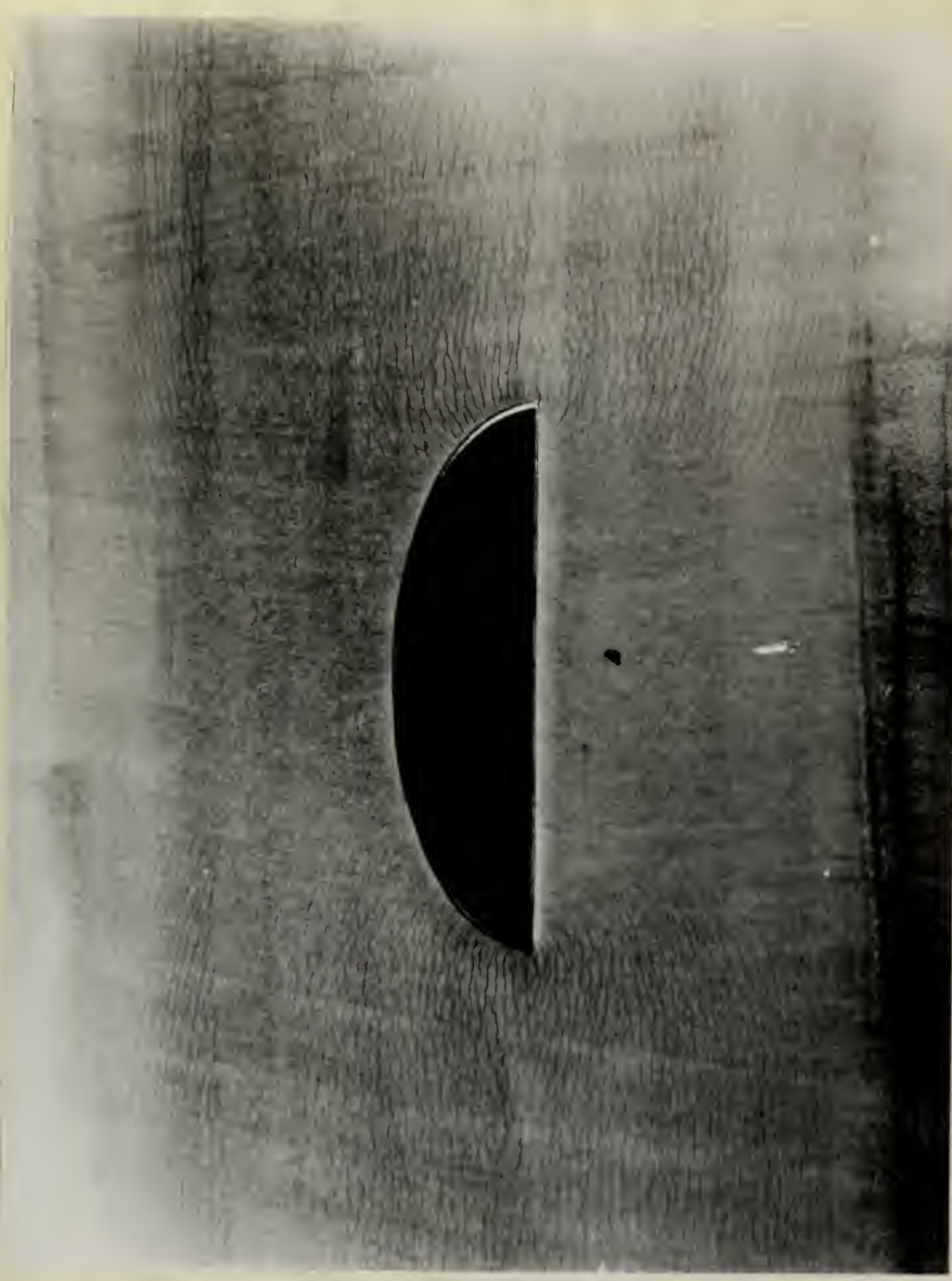


Fig. 6

Close-up view of semi-ellipse of plate #1 after test run showing isostatics. An isostatic is a line of failure of the coating. Cracks first appeared at the corners and as the load was increased the cracks gradually appeared over whole plate.

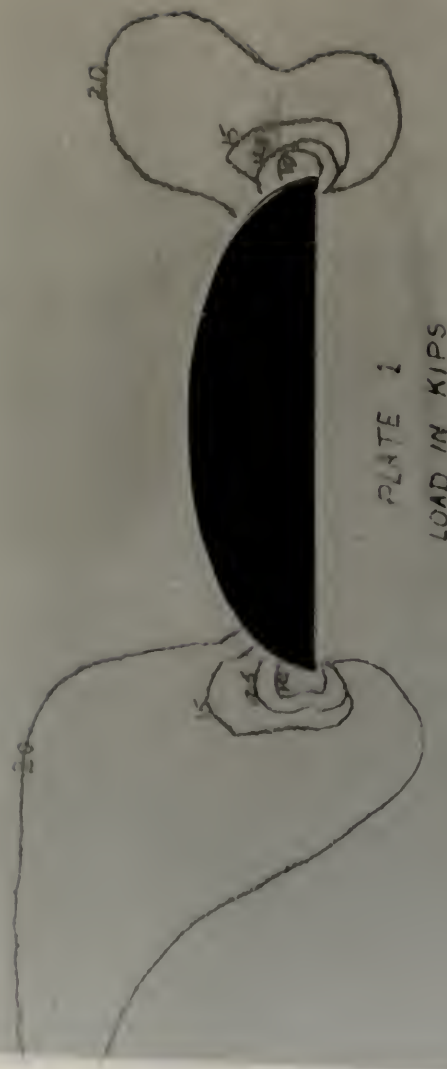


Fig. 7

Plate 1 with isostatics for loads of 10 kips, 12.5 kips, 15 kips and 20 kips. The isostatics are easily seen in the large 20 kips loop to the left. This loop was probably due to an unequal pull on this particular test run or possibly due to a weak area in the plate in that region.





Fig. 8

Plate 1, showing close up view of isoelectrics for loads 1.5 kips to 3.0 kips.



Fig. 9

Plate 2 with isoelectricity for loads 7.5 kips to 30 kips.



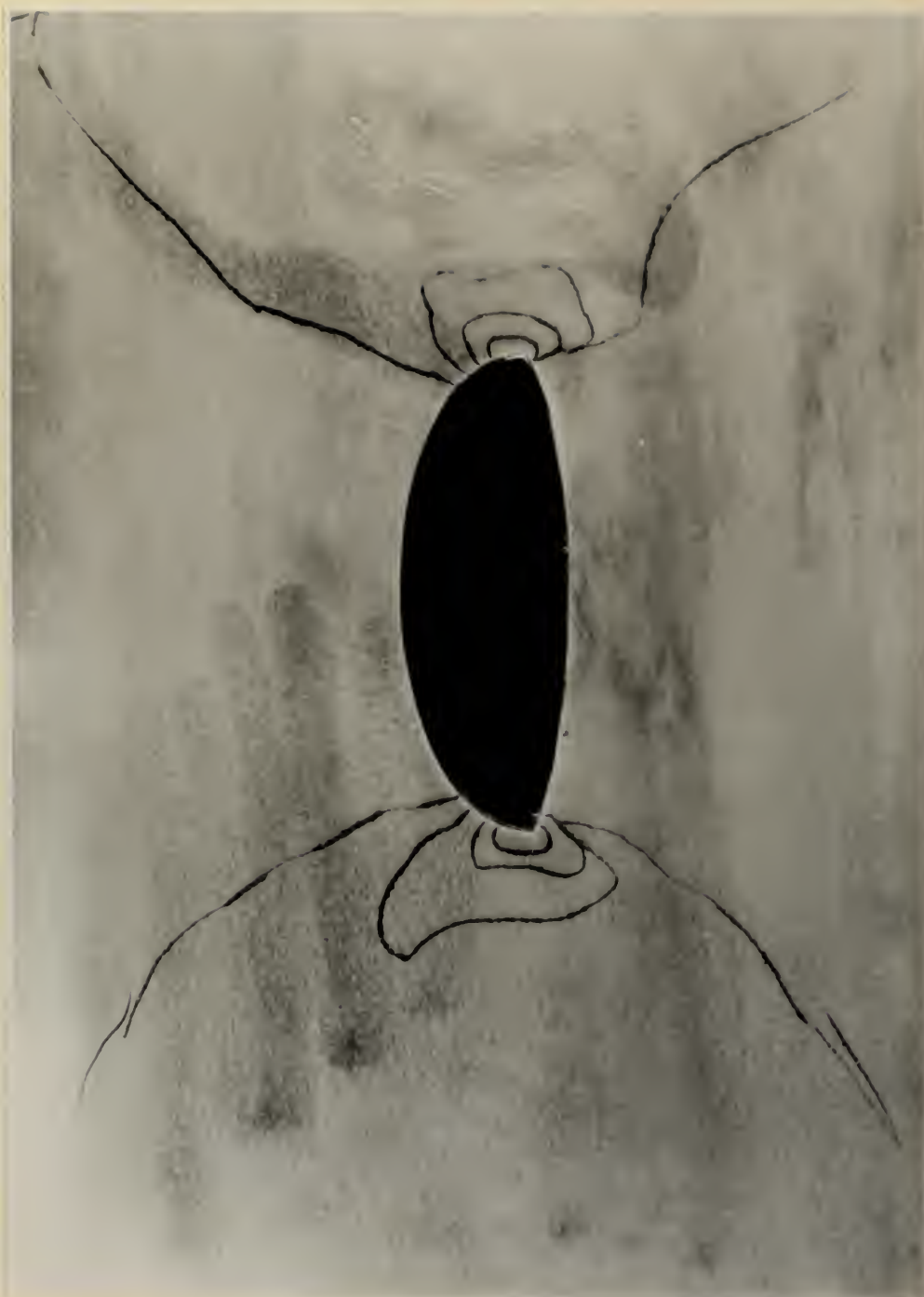


Fig. 10

Close-up view of plate #5 showing isostatistics for loads 5 kips, 7.5 kips, 10 kips and 15 kips. Isostatistics may also be seen in the large loop to the left.



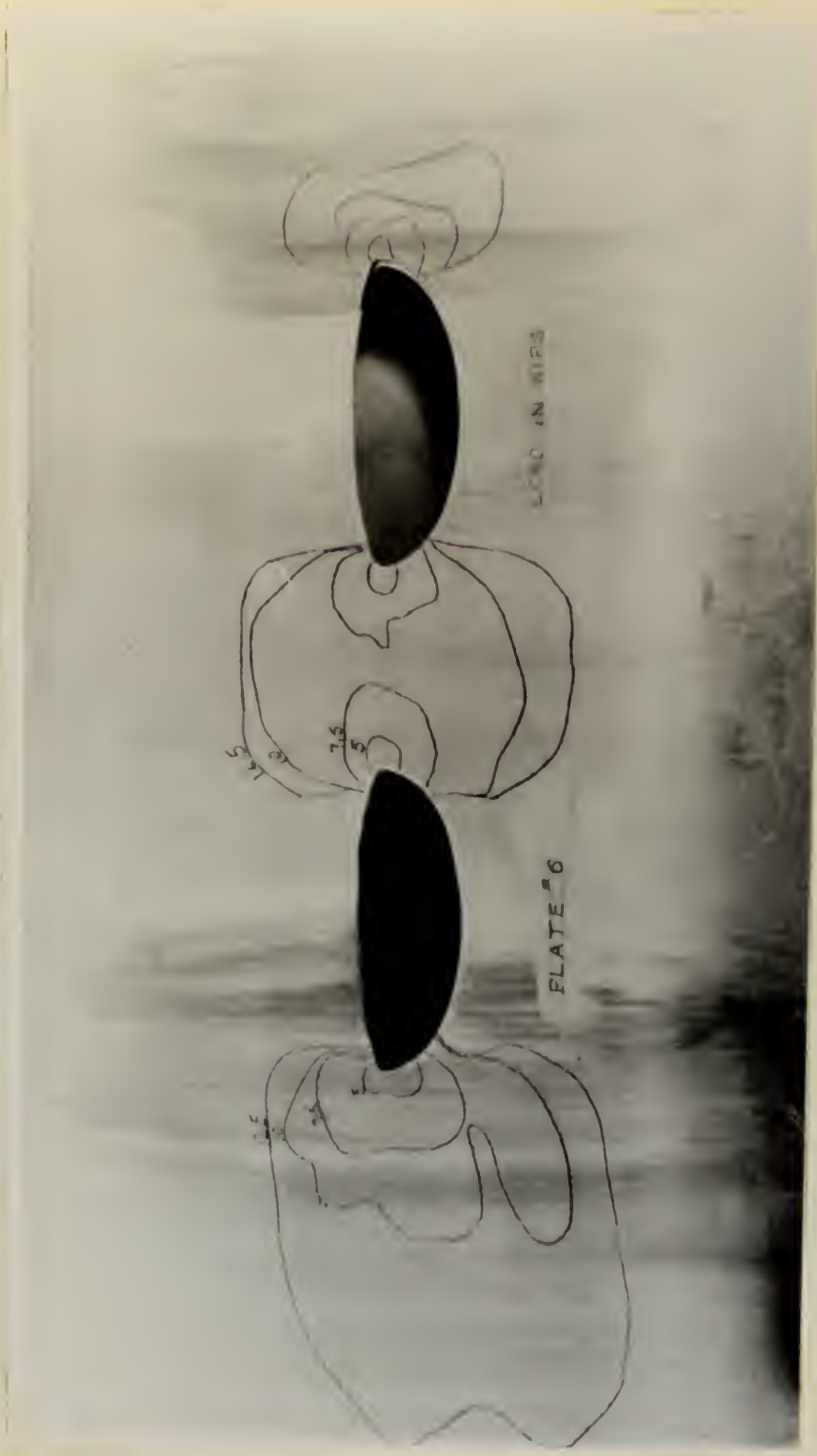


Fig. 11

Wide-view of plate #6 showing isocentatics for loads of 5 kips, 7.5 kips, 10 kips, 12.5 kips.





FIG. 12
Close-up view of plate #6 showing isotherms
for loads of 5 kips to 12.5 kips.






Fig. 13

Plate 7, showing isostatics for loads 7.5 kips to 25 kips. The isostatics may also be seen.



Fig. 14

Close-up view of the three $1\frac{1}{2}$ " circular openings of plate #10 after it had been tested. The heavy lines are isoelectrics for loads of 5 kips, 10 kips, 15 kips, and 20 kips. An isoelectric is a line joining the ends of the cracks formed in the lacquer for a particular load. For instance, a load of 5 kips was applied to the plate and the ends of all cracks were connected by a scratch mark which is the smallest ring near the ends of the horizontal diameter of the circles. The load was increased to 10 kips and the ends of the new cracks were joined by a scratch mark which is the next largest ring, and so on up to 20 kips. The plate was etched with red dye to facilitate photographing.

BIBLIOGRAPHY

1. B. T. Dibble and J. R. Wilson, "Investigation of Sensitization of Brittle Coatings", Master Thesis, Civil Engineering Department, R.I.I., September, 1948.
2. A. V. deForest and G. Ellis, "Brittle Lacquers", Aeronautical Sciences, Vol. 7, No. 5, March 5, 1940.
3. A. V. deForest, G. Ellis and F. E. Stern, "Brittle Coatings for Quantitative Strain Measurements", Journal of Applied Mechanics, Trans. ASME, Vol. 64, 1942.
4. A. J. Durelli, "What Kind of Information Does Brittle Lacquer Give?", Product Engineering, June, 1948, July, 1948.
5. Operating Instructions for Stresscoat, Magneflux Corporation, Chicago, Illinois.
6. Max M. Frocht, "Factors of Stress Concentration Photo-elastically Determined", ASME Transactions, 1935.
7. George H. Neugebauer, "Stress Concentration Factors and Their Effect on Design", Product Engineering, February, 1943.
8. A. C. J. Bowland, "On the Stresses in the Neighborhood of a Circular Hole in a Strip Under Tension", Phil. Trans. of the Royal Society of London, Series A., Vol. 229, 1929.
9. S. Timoshenko, Strength of Materials, Part II, 1943.

BIBLIOGRAPHY

1. H. F. Hippie and J. E. Wilson, "Investigation of
Construction of Buick Castings," Buick
Works, Civil Engineering Department, N.Y.C.,
September, 1948.
2. A. V. Gerasimov and A. E. Hill, "Buick Castings,"
Mathematical Sciences, Vol. V, No. 2,
March 4, 1949.
3. A. V. Gerasimov, A. E. Hill and J. E. Wilson, "Buick
Castings for Quantitative Buick Castings,"
Journal of Applied Mechanics, Trans. ASME,
Vol. 64, 1947.
4. A. J. Lavelle, "Buick Castings of Buick Castings
Castings," Trans. ASME, Vol. 64, 1947.
5. Operating Instructions for Buick Castings, Buick
Corporation, Chicago, Illinois.
6. H. F. Hippie, "Buick Castings of Buick Castings,"
Buick Castings, 1948.
7. George H. Gerasimov, "Buick Castings of Buick
Castings," Trans. ASME, Vol. 64, 1947.
8. A. J. Lavelle, "Buick Castings of Buick Castings
Castings," Trans. ASME, Vol. 64, 1947.
9. A. J. Lavelle, "Buick Castings of Buick Castings
Castings," Trans. ASME, Vol. 64, 1947.

INDEX

Abstract	1
Conclusions. . . . .	.19
Creep. . . . .	.14
Creep Correction Curve	Fig. 3
Data	
Run 1.....	.24
Run 2.....	.25
Run 3.....	.26
Run 4.....	.27
Run 5.....	.28
Run 6.....	.29
Run 7.....	.30
Run 8.....	.31
Run 9.....	.32
Run 10.....	.33
Factors.....	.34
Etchant. . . . .	.35
Factors(final) . . . . .	.34
Heat Treatment	
Explanation of. . . . .	.10
Future use of . . . . .	.17
Test runs using . . . . .	.24,25,26,31,32, 33
Illustrations.	35 to 49
Introduction	2
Isoenthetics. . .	
Definition. . . . .	.35
Illustrations . . . . .	.38 to .48
Isostatics	
Definition. . . . .	.35
Illustrations . . . . .	.38 to .48
Jig	
Design of.	9
Drawing of . . . . .	.36
Pillar.	4, 8

Index

Abolition	1
Abolition	12
Abolition	13
Abolition	14
Abolition	15
Abolition	16
Abolition	17
Abolition	18
Abolition	19
Abolition	20
Abolition	21
Abolition	22
Abolition	23
Abolition	24
Abolition	25
Abolition	26
Abolition	27
Abolition	28
Abolition	29
Abolition	30
Abolition	31
Abolition	32
Abolition	33
Abolition	34
Abolition	35
Abolition	36
Abolition	37
Abolition	38
Abolition	39
Abolition	40
Abolition	41
Abolition	42
Abolition	43
Abolition	44
Abolition	45
Abolition	46
Abolition	47
Abolition	48
Abolition	49
Abolition	50
Abolition	51
Abolition	52
Abolition	53
Abolition	54
Abolition	55
Abolition	56
Abolition	57
Abolition	58
Abolition	59
Abolition	60
Abolition	61
Abolition	62
Abolition	63
Abolition	64
Abolition	65
Abolition	66
Abolition	67
Abolition	68
Abolition	69
Abolition	70
Abolition	71
Abolition	72
Abolition	73
Abolition	74
Abolition	75
Abolition	76
Abolition	77
Abolition	78
Abolition	79
Abolition	80
Abolition	81
Abolition	82
Abolition	83
Abolition	84
Abolition	85
Abolition	86
Abolition	87
Abolition	88
Abolition	89
Abolition	90
Abolition	91
Abolition	92
Abolition	93
Abolition	94
Abolition	95
Abolition	96
Abolition	97
Abolition	98
Abolition	99
Abolition	100

Preparation of Materials	
Jig.	9
Plates	6
Stress Concentration Factor	
Definition	2
Final Factors.	34
Suggestions for future investigation.	22
Temperature Correction.	13

Table

Preparation of material	1
.....	2
.....	3
.....	4
.....	5
.....	6
.....	7
.....	8
.....	9
.....	10
.....	11
.....	12
.....	13
.....	14
.....	15
.....	16
.....	17
.....	18
.....	19
.....	20
.....	21
.....	22
.....	23
.....	24
.....	25
.....	26
.....	27
.....	28
.....	29
.....	30
.....	31
.....	32
.....	33
.....	34
.....	35
.....	36
.....	37
.....	38
.....	39
.....	40
.....	41
.....	42
.....	43
.....	44
.....	45
.....	46
.....	47
.....	48
.....	49
.....	50
.....	51
.....	52
.....	53
.....	54
.....	55
.....	56
.....	57
.....	58
.....	59
.....	60
.....	61
.....	62
.....	63
.....	64
.....	65
.....	66
.....	67
.....	68
.....	69
.....	70
.....	71
.....	72
.....	73
.....	74
.....	75
.....	76
.....	77
.....	78
.....	79
.....	80
.....	81
.....	82
.....	83
.....	84
.....	85
.....	86
.....	87
.....	88
.....	89
.....	90
.....	91
.....	92
.....	93
.....	94
.....	95
.....	96
.....	97
.....	98
.....	99
.....	100

.....

.....

.....

.....



Thesis

7476

M35 Marquardt

An investigation of
stress concentration
factors around selected
openings using the
brittle lacquer technique.

Thesis

7476

M35 Marquardt

An investigation of
stress concentration
factors around selected
openings using the
brittle lacquer technique.

thesM35

An investigation of stress concentration



3 2768 002 12785 4

DUDLEY KNOX LIBRARY